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AD-A244 304

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE 9-23-91	3. REPORT TYPE AND DATES COVERED Interim Technical Report

4. TITLE AND SUBTITLE

Pump Wavelength Tuning of a Near Infrared Optical Parametric

5. FUNDING NUMBERS

DAAL03-91-G-0099

2

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U. S. Army Research Office
P. O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

ARO 28472.1-PH

11. SUPPLEMENTARY NOTES

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12a. DISTRIBUTION/AVAILABILITY STATEMENT

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12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Optical parametric conversion in a Potassium Titanyl Phosphate crystal(KTP) using a tunable alexandrite laser was investigated as a function of pump wavelengths in the 700-800 nm region. Threshold energies and slope efficiencies for a doubly resonant oscillator configuration were measured for pump wavelengths of 744 nm, 766 nm, and 780 nm. A theoretical analysis using Sellmeier's equations and phase matching conditions provide good agreement with experimentally measured values of signal and idler wavelengths as a function of the pump wavelengths.

14. SUBJECT TERMS	15. NUMBER OF PAGES
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

Pump Wavelength Tuning of a Near Infrared Optical Parametric

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ABSTRACT

Optical parametric conversion in a Potassium Titanyl Phosphate crystal(KTP) using a tunable alexandrite laser was investigated as a function of pump wavelengths in the 700-800 nm region. Threshold energies and slope efficiencies for a doubly resonant oscillator configuration were measured for pump wavelengths of 744 nm, 766 nm, and 780 nm. A theoretical analysis using Sellmeier's equations and phase matching conditions provide good agreement with experimentally measured values of signal and idler wavelengths as a function of the pump wavelengths.

Optical parametric oscillators and amplifiers provide a way to generate tunable radiation and have been the subject of many investigations and reviews.[1-3] Potassium Titanyl Phosphate ($KTiOPO_4$, henceforth referred as KTP) is a relatively new material possessing a number of very useful optical and material properties.[4-6] Its high nonlinear coefficients, high damage threshold, wide acceptance angles, and thermally stable phase-matching attributes make it useful for parametric conversion. KTP is transparent from 400 nm to 4.2 μm so phase matching for a number of parametric processes could be obtained over this entire range. Optical parametric conversion in KTP has been recently demonstrated using pump wavelengths of 526 nm, 532 nm and 1064 nm.[7-9]

Most of the previous investigations related to optical parametric oscillators(OPOs) have either used angle tuning or temperature tuning of the refractive index to determine the output wavelength. A previous study by Weiss and Goldberg[10] used three different pump wavelengths from a discretely tunable HF laser to generate signal and idler wavelengths in CdSe. In this study, we report optical parametric conversion using a continuously tunable pump source to tune the output wavelength. An alexandrite laser with a tuning range of 720-300 nm was used as the excitation source. Our results demonstrate extendibility of the tuning range of this laser to wavelengths between 1.40 and 1.63 μm using a KTP crystal in an OPO cavity.

Potassium Titanyl Phosphate belongs to the orthorhombic crystal system, and hence is optically biaxial. The mutually orthogonal principal axes of the index ellipsoid are defined such that $n_x < n_y < n_z$, and the optical axes lie in the x-z plane. A flux-grown KTP crystal was cut for Type II phase-matching with $\phi=0°$ and $\theta= 54°$. The interaction length of the crystal was 10.5 mm. The end faces of the crystal were polished flat and parallel but not AR coated. To investigate parametric oscillations we used a doubly resonant oscillator (DRO) configuration because of its low threshold pump energies.[1] The optical cavity consisted of a flat mirror highly reflecting between 1.3-1.8 μm and highly transmitting between 700-800 nm. The output coupler was 98% reflecting between 1.3-1.8 μm with a one-meter radius of curvature The mirrors were separated by 5 cm and the crystal was mounted on a rotation stage with the Y-axis in the vertical direction.

The cavity was longitudinally pumped with an alexandrite pump pulse polarized along the Y-axis of the crystal such that the pump beam is an ordinary ray. The pump laser was operated at 7 Hz and its output consisted of a series of 300-nsec pulses in a 60- μsec envelope. The unfocused pump beam size incident on the crystal was 0.8 mm ($1/e^2$ intensity radius). This is much larger than the value for optimum coupling needed to achieve mode matching. The output consisting of signal and idler wavelengths was monitored with an InSb detector after passing through a silicon filter to block the transmitted pump wavelength, and a 1/4-meter SPEX monochromator with a grating blazed at 1.25 μm (600 grooves/mm).

The experimental results of output wavelengths as a function of pump wavelengths in the 700-800 nm region are shown by open circles in Fig. 1. It can be seen from this figure that for a pump wavelength of 766 nm the signal and idler wavelengths are approximately degenerate. The signal output varies from 1.527 to 1.540 μm whereas the idler output varies from 1.399 to 1.616 μm as the pump wavelength varies from 732 nm to 788 nm. The output signal wave is polarized along the Y-axis of the crystal (o-wave) where as the idler wave is polarized in the x-z plane (e-wave). The solid curves shown in the figure were calculated using Sellmeier's equations given by Kato[5,11] and a method to calculate phase matching parameters outlined by Yao and Fahlen.[12] The calculated phase matching angle for the 766 nm pump wavelength giving degenerate output was found to be 54.35°. this value of θ was used in calculating the solid curves shown in Fig. 1. The results show a very good agreement between measured experimental values (within + 3 nm) and the calculated values.

The slope efficiencies and the threshold pump energies were measured for pump wavelengths of 744 nm, 766 nm, and 780 nm. The total output of signal and idler beams was passed through a silicon filter and monitored with the help of a dual-probe energy meter. The results for a pump wavelength of 766 nm yielding degenerate output are shown in Fig. 2. A slope efficiency of 2.25% and threshold energy of 1.25 mJ corresponding to 60 mJ/cm^2 (for a pump beam radius 0.8 mm at 1/e^2 intensity) energy fluence were obtained. The apparent saturation at high pump powers is due to instabilities in the pump laser. A calculation of the threshold energy fluence for a single pass doubly resonant oscillator (DRO) at a pump wavelength of 766 nm and degenerate output at 1.532 μm using the theory of Byer[13] predicts a value of 5.2 mJ, assuming 2% cavity losses for both signal and idler beams. Our observed value of the threshold pump energy is in reasonable agreement with the calculated value. Similar values of threshold energies and slope efficiencies, within the experimental error, were also observed for 744 nm and 780 nm pump wavelengths. This demonstrates that there is a little change in OPO operational parameters across output tuning range when the technique of pump beam tuning is used.

In conclusion, we have obtained a 2.25% slope efficiency and an energy threshold fluence of 60 mJ/cm^2 for a DRO cavity configuration of a KTP OPO pumped by a tunable alexandrite laser. By optimizing experimental parameters such as AR coating the sample, better cavity design, inhibiting feedback between the oscillator and the pump, and improving the spatial profile of the pump beam, significantly better efficiencies should be obtainable. The demonstration of relatively constant OPO operational parameters obtained with pump beam tuning, shows that this is an important technique for use of OPO's with tunable pump sources. With the rapid development of new tunable solid state lasers (alexandrite, titanium doped sapphire, chromium doped forsterite, emerald, chromium doped $LiCaAlF_6$, etc.) as well as dye lasers for pump sources, pump beam tuned OPOs may be important devices for extending the range of available laser wavelengths. Since the cavity configuration is a DRO, large instabilities in the output were observed compared to those seen in a singly resonant oscillator configuration. Efforts are in progress to obtain optical parametric conversion using a SRO configuration for this system.

ACKNOWLEDGEMENTS

This research was sponsored by the U.S. Army Research Office. The authors benefitted greatly from many helpful discussions with Drs. Gregory J. Quarles and Roger J. Reeves.

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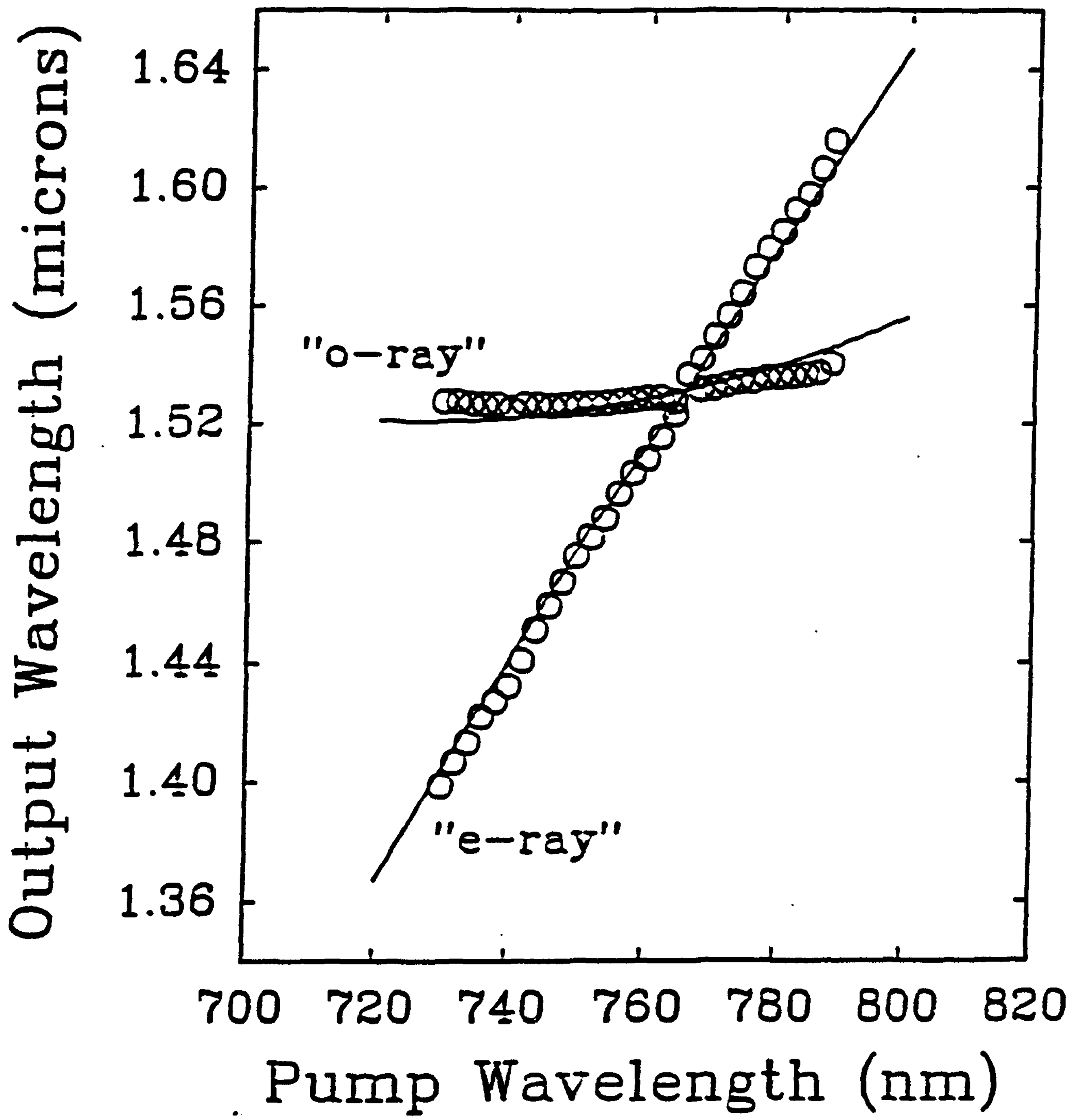
FIGURE CAPTIONS

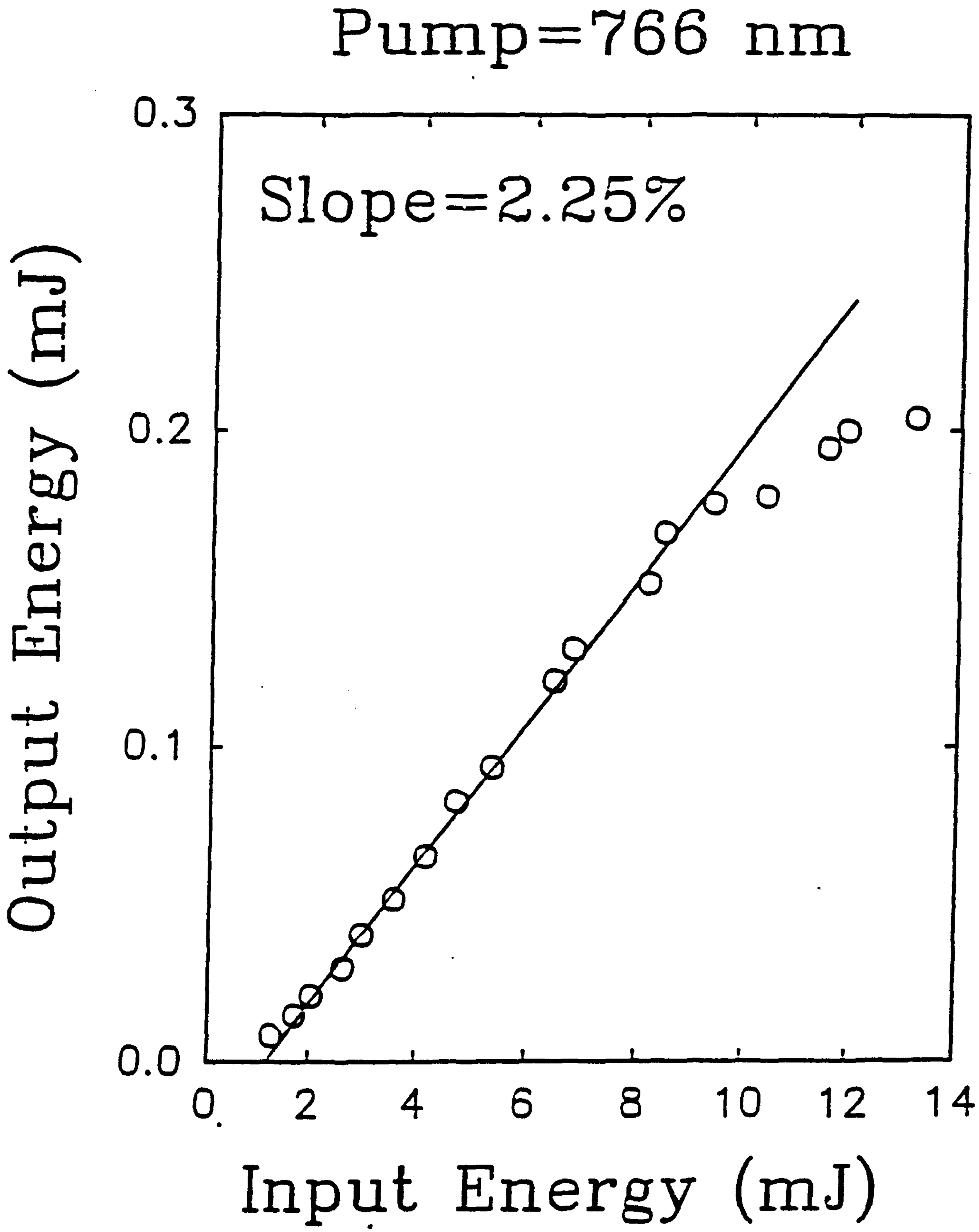
1. The signal and idler wave outputs as a function of pump wavelength. The open circles represent experimental data points and the solid lines are theoritically calculated curves as per discussion in the text.
2. Pump energy threshold and slope efficiency of the signal and idler output waves for a pump wavelength of 766 nm. The highest four points were not included in determining the slope of the curve.

Figure 1.



Output Wavelength (microns)
1.64
1.60
1.56
1.52
1.48
1.44
1.40
1.36
"o-ray"
"e-ray"
700
720
740
760
780
800
820
Pump Wavelength (nm)

Figure 2



Pump=766 nm
Slope=2.25%
0.3
0.2
0.1
0.0
Output Energy (mJ)
0
2
4
6
8
10
12
14
Input Energy (mJ)